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The Effects of Drought Stress on Squash Plants

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INTRODUCTION

With competition for water resources increasing drastically around the globe agriculturally, industrially, and domestically, it is paramount that stores are utilized sustainably and responsibly (Jury & Vaux, 2005). Understanding the mechanisms at work behind a plant's response to drought stress is crucial before we can integrate effective strategies for combating reduced availability of water. Drought affects plants differently depending on their inherited adaptations and their ability to acclimate. Investigating how different plants respond may give a better foundation for development of hardy breeds, appropriate irrigation techniques, and climatic placement.

OBJECTIVE:
This study examines the varying physiological changes that may occur when squash (*Cucurbita pepo* L.) plants experience drought as opposed to a control group of squash plants. Factors measured include specific leaf area, minimum transpiration, minimum conductance, water potential, soil to apical meristem height over time, true leaf count over time, and dry biomass.

METHODS AND MATERIALS

- **Set-Up & Growth Measures:** *Cucurbita pepo* L. open pollinated hybrid honey boat delicata squash (Baggett & Kean, 1990) seedlings were planted at 3 weeks into plastic pots with volumes of approximately 33,080.29 cm^3 and arranged in a randomized plot. Soil medium was Pro-Mix BX Mycorrhizae. Growth measures of stem base to apical meristem height (mm) and true leaf counts were recorded weekly for 7 weeks. Biomass was obtained by drying the entirety of the plant (excluding roots) after all measures were taken at the end of 7 weeks. Drought plants received water (mixed with Miracle-Gro all-purpose fertilizer) filled to the pot brim one day a week for 6 weeks. Control plants were watered three times a week and fertilized concurrently with one of those water treatments. The experiment was conducted in heated greenhouse conditions with supplemental metal halide lighting between 7am and 7pm each day.
- **Specific Leaf Area (SLA):** Leaves were obtained and then scanned using ImageJ Software (NIH, USA, http://rsb.info.nih.gov/ij/) to obtain cm^2 area. Leaves were then dried and weighed in grams. SLA was calculated by dividing area by weight (cm^2/g).
- **Minimum Transpiration & Conductance:** Leaves were obtained, the petiole ends were wrapped in wax, and the leaves were weighed at 10-minute increments for 1 hour. Results were formatted into linear graphs using Excel Version 14.6.1 to obtain slope, which could then be translated into minimum transpiration rate and minimum conductance using simple calculations. The leaves were scanned using ImageJ for area (cm^2) after the experiment.
- **Water Potential:** Leaves were obtained by cutting the leaf tissue along the edges of the midvein and cutting the petioles to have about 5 cm in length. Leaves were then inserted into a pressure chamber (PMS Instrument Company, Albany OR & Soil Moisture Equipment Corporation, Santa Barbara CA) and measured for the pressure required to bring water to the severed end of the petiole (MPa). These steps were completed for dark-adapted and light-adapted conditions.

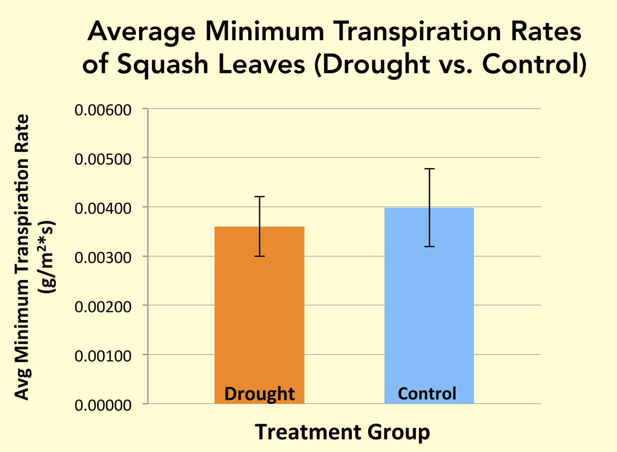


Figure 1. Comparison of average minimum transpiration rates between drought and control honey boat delicata squash leaves. Bars are means ±1 SD, n=5; **t_8=0.853, P>0.05**

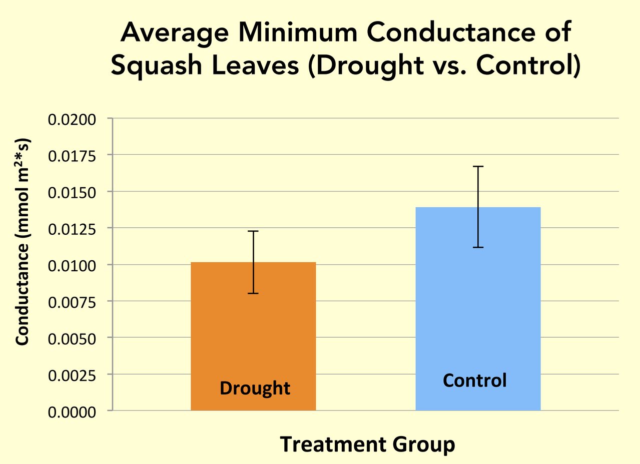


Figure 2. Comparison of average minimum conductance between drought and control honey boat delicata squash leaves. Bars are means ±1 SD, n=5; **t_8=0.835, P>0.05**

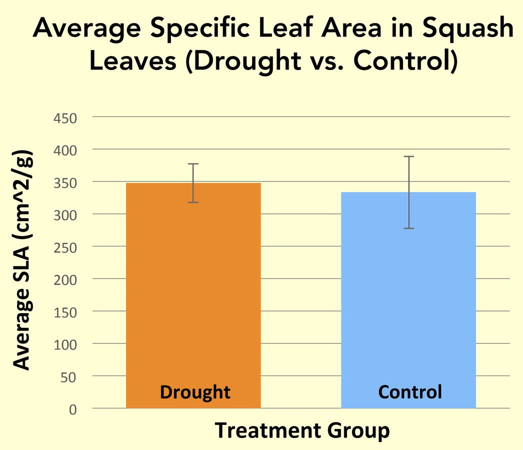


Figure 3. Comparison of the average specific leaf area between drought and control honey boat delicata squash leaves. Bars are means ±1 SD, n=3-5; **t_6=0.487, P>0.05**

Image 1. Condition of a drought-treated squash plant (left) compared to that of a control squash plant (right) after 6 weeks of treatment.

Water Potential Differences

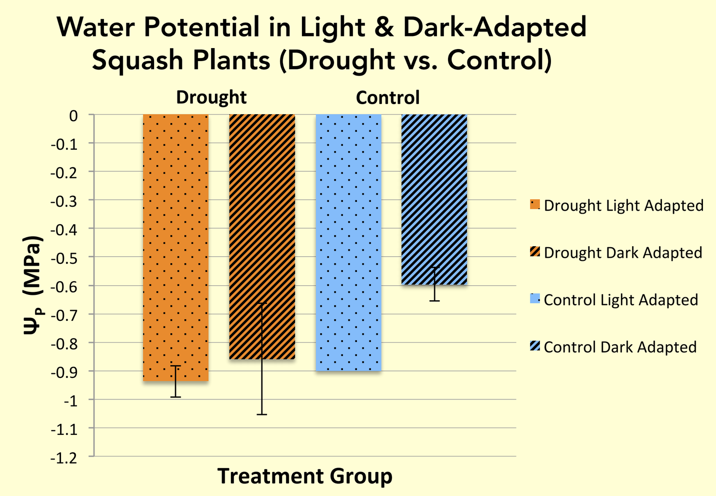


Figure 4. Comparison of water potential (Ψ_P) in drought plants and control plants in light conditions vs. dark conditions. Bars are means ±1 SD, n=3-5

Drought vs. control in light conditions: **t_4=1.16, P>0.05**

Drought vs. control in dark conditions: **t_8=2.88, P<0.025**

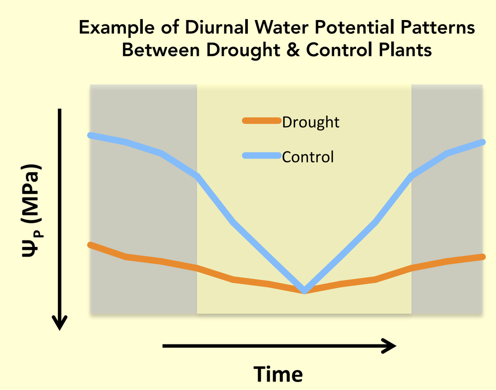


Figure 5. ***Modeled prediction*** of leaf water potential (Ψ_P) changes throughout the course of the day (yellow) and night (grey) in drought-treated plants and controls (BI330, 2016). *(Data points generated for the sake of example, **not** acquired from this experiment's data).*

Image 2. (left) Squash plant responding to drought stress by wilting and rolling leaves to minimize surface area vulnerable to transpiration; (bottom right) control squash plant leaves with normal water conditions displaying normal turgidity and exposed surface area

RESULTS

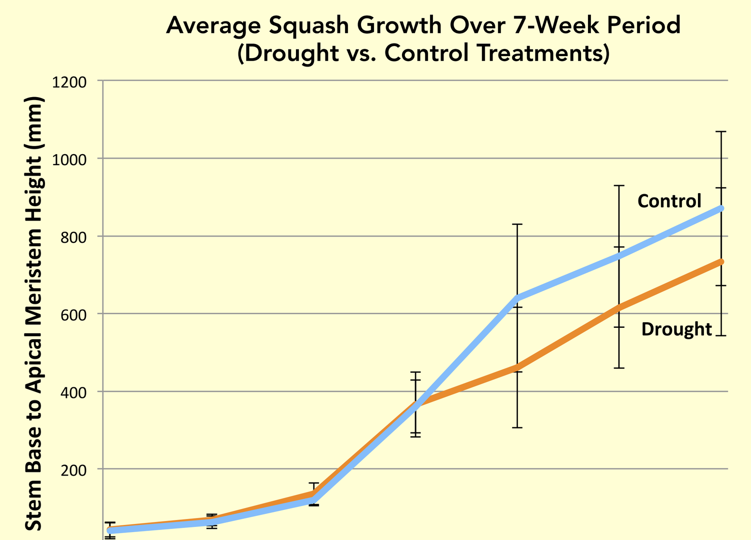
- Average SLA, minimum transpiration, and minimum conductance measures displayed no significant differences between treatment groups (**Figures 1-3**). This did not support my hypothesis, which was based on the idea that drought plants would need to conserve water by having lower SLA and transpiration and conductance rates. Perhaps stress response at these levels has been selectively bred out of these plants, which are primarily used for agriculture.
- Average water potential data exhibited a significant difference between drought-treated and control plants in dark conditions, but showed similar MPa readings in light conditions. I expected more negative water potential values in both conditions for the drought-treated plants. However, these results make sense in that drought-subjected plants have a narrower operating range of water potentials, varying between very negative during the day (pulling water in) to slightly less negative at night (in recovery, but still pulling on water sources). The plants find a balance between pulling up water and also preventing cavitation damage from potentials that are too negative. Perhaps there is no difference between drought-treated and control light-adapted potentials because their genetic makeup sets a strict minimum for how much they can pull during warmer daytime conditions (**Figures 4, 5**).
- Average squash growth over time progressed similarly (**Figures 6, 7**), with minimally higher values for control plants. Even average biomass measures just missed the mark for being statistically significant (**Figure 8**). There did appear to be possible areas (proximity to metal halide lights) in the greenhouse plot that facilitated greater growth, irrespective of treatment group, which may have confounded the growth data.

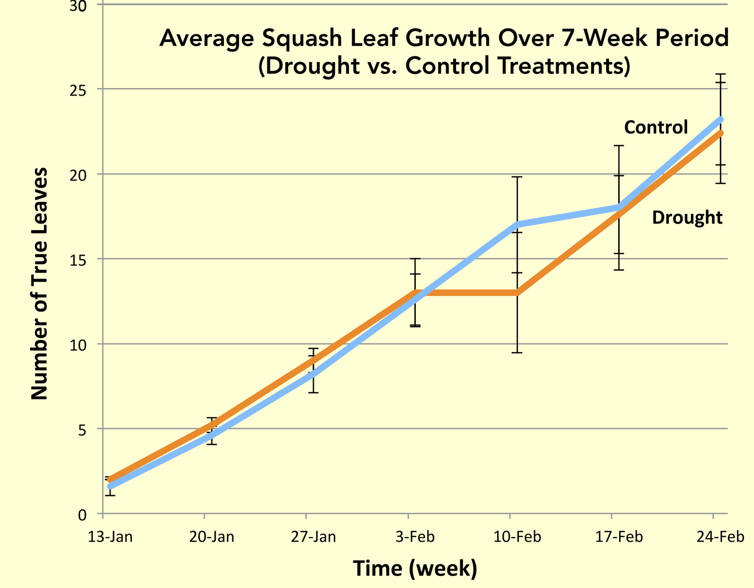
Growth Comparisons

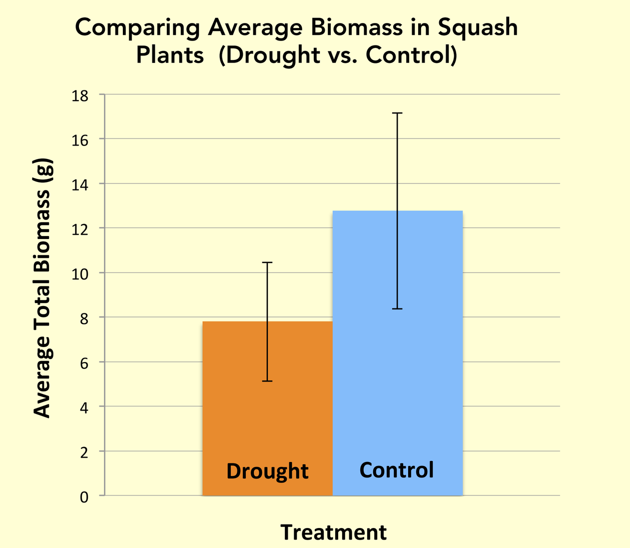
Figure 6. ***(top right)*** Tracking the average number of true leaves each week in honey boat delicata squash drought-treated and control plants. Points are means ±1 SD, n=5.

Figure 7. ***(bottom right)*** Tracking the average number of true leaves each week in honey boat delicata squash drought-treated and control plants. . Points are means ±1 SD, n=5.

Figure 8. ***(bottom left)*** Comparison of the average total biomass in honey boat delicata squash drought-treated and control plants weighed at the end of the 7-week period; **t_8=2.162, P>0.05**







CONCLUSION

Honey boat delicata squash plants may not show significant differences in these measured factors between drought and control treatments because they have been bred for productivity and yield verses ability to respond to stress. Water potential was more negative for drought plants in dark conditions, though. Significantly lower potential in these plants during recovery time (dark conditions) indicates successful application of drought treatment. Drought plants exhibit a narrower water potential range diurnally due their attempt to maximize water uptake while still preventing cavitation as the day goes on. More research with greater sample sizes and an additional wild type group must be conducted to solidify if this breed of squash really does not respond to stress adequately.

REFERENCES & ACKNOWLEDGEMENTS

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